

Preface

Water, as well as other fluids intended for human use, are characterized by many parameters, most of which can be measured directly with high temporal resolution, high accuracy and low effort. Take temperature, conductivity, turbidity, density and composition—there is a large number of techniques available to probe small and large samples to obtain a value in near-real-time and/or to rapidly control a process.

One crucial parameter is the microbiological quality of utilized liquids. The presence of microorganisms in a sample can still not be determined readily. Today researchers and practitioners in the fields of hygiene, healthcare and other disciplines still rely on culture methods established more than a century ago to assess the microbiological quality of water. These culture-base microbial assays, that require the plating of a sample on growth agar, incubating and counting colonies after typically 24 hours, are still state-of-the-art. This process demands elaborate sampling and laboratory work, is time- and staff consuming and consequentially costly. It takes more than a working day to gain results that are critical for a health-related surveillance of water resources of liquid systems. Therefore, these microbiological standard assays can barely be integrated into early-warning systems and dynamic process control.

Online and near-real-time measurements of traditional physical parameters have added great value to many fields of environmental research as well as various industries. They can be seen as the core of the industry where, a new trend in manufacturing is poised at increasing flexibility and reducing costs. In environmental research the on-site and near-real-time monitoring of physico-chemical parameters of water is well established, commonly used and a core component of sustainable water resource management. For microbial and biochemical parameters, however, there is still a lack of technologies and assays that allow such a high temporal resolution of measurement. Decisive technological progress occurred in the last few years, generating new methods and assays that are able to highlight the microbial quality of water and liquids in near-real-time. While some of these methods and related research are still emerging, they have enormous potential to enhance health-related assessment of environmental, medical or

industrial systems. It can be expected that near-real-time microbial methods will be the cornerstone of water quality monitoring and industrial process control in the near future. Imagine, for instance, a drinking water or sewage treatment plant, where disinfection is carried out. Today, chemicals need to be added in excess to be 'on the safe side', or UV light has to be provided at installed capacity. Now if an operator were to instantly measure the microbiological contamination level of either inlet or outlet stream, he could automatically adjust the degree of required disinfection to reach the target level, thereby saving cost, relieving the environment and adding safety to the process, now closely monitored. This is just one of the many potential use cases of rapid microbiological sensors.

In this handbook, leading experts contribute review articles on frontiers in microbiological detection research—emerging and state-of-the-art online and near-real-time methods of microorganism detection and indication.

This book presents cutting edge research, developments and applications with regard to online and near-real-time microbiology, where 'near-real-time' is understood as obtaining a quantitative or at least qualitative measurement result within 15–30 minutes, which is really fast as compared to traditional methods that show a time lag often in excess of 24 hours.

The aim was to obtain a balance between chapters from industry and contributions from academia, covering the broad field of microbiological quality of water and liquids in natural, industrial and medical systems.

In their chapter titled 'Rapid, Automated and Online Detection of Indicator Bacteria in Water', Trude Movig and others describe how microbiological water quality can be monitored by analyzing fecal indicator bacteria, like thermotolerant coliforms and *E. coli* based on their enzymatic activities; chromogenic substances are utilized for the detection of β -D-galactosidase and β -D-glucuronidase (GLUC) enzyme activities, respectively, to indicate the presence of these bacteria, which are well-established indicators for fecal contamination that can carry other pathogenic microorganisms. The chapter discusses analyzers that are in market today and compares their performance based on results generated in 0.25 to 2 hours as compared to automated growth methods that have a typical analysis time of 12–17 hours.

The next chapter titled 'Real-time Monitoring of Enzymatic Activity in Water Resources' by Philipp Stadler and others presents the application of a novel concept for automated online monitoring of enzymatic activity in different water resources, specifically alluvial porous groundwater, karstic groundwater and surface water. Two commercially available prototypes for beta-D-glucuronidase (GLUC) activity determination were subjected to an extensive field trial in an Austrian catchment area. The experimental results of Stadler et al. show that on-site measured GLUC signals reflect the

characteristic transport and discharge dynamics of the observed catchment. Reference analytics by means of culture-based *E. coli* indicate that GLUC measurements are not a proxy for standard microbiological assays and that relations of GLUC activity and culture-based *E. coli* depend on the observed habitat. Comparison of GLUC measurements gathered with independently-constructed prototypes showed comparable results.

'Advances in Electrochemically Active Bacteria Physiology and Ecology' by Ana C. Marques and others presents electrochemically active bacteria (EAB), which constitute a very interesting and promising class of bacteria. However, today's screening methods are based on MFC (microbial fuel cell) engineering principles, which are relatively slow (~5 to 6 days) and expensive. So, the development of rapid and simple screening methods using low cost and available materials are today a key issue to aid in the better understanding of such types of bacteria, thus allowing further refining in the performance of electrochemically active bacteria for use in biotechnological applications.

Sevcin Aydin presents the 'Application of Quantitative Real-time PCR for Microbial Community Analysis in Environmental Research' in his chapter. Polymerase chain reaction (PCR) operates by extracting nucleic acids and their enzymatic amplification of certain genes from the complex genomic DNA of environmental samples. Aydin discusses the molecular approach of PCR for near-real-time bacterial detection.

The next chapter addresses the measurement of bacteria in a completely different fluid than water—Gregor Tegl and others describe the '*In Vitro* Diagnostics for Early Detection of Bacterial Wound Infection', where they use enzymes produced by the infected wound to rapidly infer bacterial colonization through a color change with an *in vitro* diagnostic (IVD) tool. Results are obtained within a compelling 15 minutes. Bacterial contamination is the basis of wound infection and affects about 10 per cent of all postoperative wounds. A high risk of infection is also reported for chronic wounds.

Jacobo Paredes and others have contributed the chapter 'Biofilm Impedance Monitoring'. Biofilms are a challenge to control and their early detection is an advisable strategy, for which the authors demonstrate impedance microbiology as a suitable approach.

Maximilian Lackner has written the chapter 'Rapid Microbial Water Quality Measurement by Automated Determination of the Fecal Indicator Bacterium *Escherichia coli*', which reviews the measurement principles, opportunities and limitations of automated microbiological measurements for process control.

Samendra P. Sherchan presents the final chapter on real-time monitoring of microorganisms in potable water using online sensors for use in SCADA (supervisory control and data acquisition) systems in large-scale water

quality monitoring programs. Multi-angle light scattering (MALS), intrinsic fluorescence and enzyme-based technology are compared and discussed, also with reference to traditional sensors and influencing factors.

The purpose of this Handbook is to serve its readers as a handy reference and give momentum to their thoughts on novel applications of the present emerging online and near-real-time methods in microbiology. It also contains a comprehensive glossary in which the most relevant terms of this novel field are defined. The new and up-to-now fairly narrow field of rapid and automated microbial assays is likely to gain significance and cost an impact on a global scale in the near future. This Handbook is the first of its kind, giving an up-to-date insight into modern monitoring and measuring techniques.

The editors and authors wish their readers many interesting insights after reading this Handbook.

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